

KY BUTTERFLY NET: AN INTERACTIVE WEB DATABASE TO FACILITATE LEPIDOPTERA RESEARCH AND EDUCATION IN KENTUCKY

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ABSTRACT. Kentucky Butterfly Net is a World Wide Web database that collects and reports distribution data for the 2,488 species of Lepidoptera (butterflies and moths) known from the state of Kentucky, USA. It includes tools for entering, editing, and curating new records. Species queries in Kentucky Butterfly Net can be initiated using either scientific or common names. Species query reports include range maps and phenology spindle diagrams dynamically generated from the data. Location queries can produce species lists of all Lepidoptera, just butterflies or just moths for 244 geographic localities, corresponding to the 120 counties of Kentucky, plus an additional 124 conservation units. To date, a total of 61,231 records covering the years 1872–present are included in the database. These data represent an important resource for both education and research on the Lepidoptera of Kentucky.

Additional key words: biogeography, climate change, citizen science, web database.

Regional guides to Lepidoptera are an important resource for both professionals and amateurs. They serve a wide variety of purposes as varied as facilitating the identification of crop pests, providing the raw data for the study of biogeography, and satisfying the curiosity of casual inquirers. In the United States important examples of such guides include the 4 volumes of *The Lepidoptera of New York and Neighboring States* (Forbes 1923, 1948, 1954, 1960), *The Lepidoptera of Florida: An Annotated Checklist* (Kimball 1965), and the 3 volumes of *A List of the Lepidoptera of Maine* (Brower 1974, 1983, 1984). For the study of butterflies and moths in Kentucky and adjacent states, Covell (1999) has been an important reference. However, these print guides have limitations. They very quickly go out of date as additional collections and observations are made (Covell & Gibson 2008, Covell *et al.* 2000, Gibson & Covell 2006), as new species are described or species names are revised (Covell *et al.* 2000), and as species distributions change over time (Gibson & Covell 2006). Regional guides can also be difficult to obtain after they go out of print, making it difficult (and sometimes expensive) for those newly interested to access the information that they contain.

To address these issues, a number of World Wide Web-based projects have been initiated (see http://www.lepsoc.org/lepidoptera_websites_databases.php). These include projects that attempt to cover Worldwide (Oehlke 2007, Pittaway & Kitching 2008), North American (Opler *et al.* 2006, Poole 1999), or national (CBIF 2006, Roy 2008), distributions of select species, or more comprehensive treatments of all Lepidopteran species in particular conservation units, such as Great Smoky Mountains National Park, USA (NPS 2007) or Area de Conservación Guanacaste, Costa Rica (Janzen & Hallwachs 2005). Our own project is a World Wide Web-based description of the known lepidopteran fauna on an intermediate geographic scale, the state of Kentucky, USA, which covers approximately 10.5 million square kilometers.

The history of Kentucky Lepidoptera studies and early publications, almost exclusively restricted to Kentucky butterflies, can be found in the "History" section of Covell (1999, pp. 2–6). Beginning in 1964, a file of data on collections and observations of all Kentucky Lepidoptera was begun by Covell from historical and current field collections and reliable observations. To add to the known state fauna, the Society of Kentucky Lepidopterists was formed in 1974,

and members have met in various localities in the state to collect specimens and record observations. Unidentified specimens were taken to various moth specialists, notably at the U. S. National Museum of Natural History (Smithsonian Institution) in Washington, DC. These colleagues identified many moths, some of them found to be new to science, and others found to represent major extensions of known ranges.

The project described here builds upon these earlier efforts to collect, organize, and share Kentucky Lepidoptera records. We have created a world wide web-based version of a Microsoft Access database, complete with tools for distributed data entry, curation, and visualization by species or locality to facilitate research and educational activities concerning the Lepidoptera of this region. This resource is known as Kentucky Butterfly Net and is available at <http://www.kybutterfly.net>.

MATERIALS AND METHODS

Database history and design. Efforts to systematically inventory the Lepidoptera of Kentucky began in 1964 with records entered by hand on large file cards, and filed alphabetically by family, genus, and species. In 1995, data were transferred from these cards to a Microsoft Excel spreadsheet to facilitate the preparation of Covell (1999), *The butterflies and moths (Lepidoptera) of Kentucky: an annotated checklist*, but data continued to be organized alphabetically. In 2002, with the assistance of Rick Ruggles, the data were transferred to Microsoft Access to create a desktop computer-based relational database.

In creating the relational Microsoft Access database, specific requirements were: to reorganize the data to store it efficiently and to facilitate queries; to include all previously recorded data, making concessions for records that are incomplete or vague; to migrate the existing data cost effectively minimizing manual re-entry; to allow queries of the data based on taxonomy, location and date; to allow the entry of new data with additional information such as GPS location; and to provide a mechanism of curation and validation of newly entered data.

As currently construed, Kentucky Butterfly Net is a Microsoft Access relational database installed on a server running Microsoft IIS (Internet Information Services) and ASP (Active Server Pages). Records for species and geographic localities must match entries that appear in the respective lookup tables. The addition of a new species to the Kentucky species list or the addition of a new conservation unit to the locality list

requires correspondence with one of the database curators. For more routine additions to the database, a series of dynamic web pages were created in ASP to permit users from remote locations to query the database or add new records over the web through a browser interface. We chose to utilize a database structure that is non-normalized to accommodate legacy data. New data are validated by automated validation routines as well as by an administrative user to ensure accuracy and completeness. Finally, queries take into account both normalized and non-normalized data to display the resulting dataset accurately.

Data entry and curation. Data entry permission is password protected to prevent hacking and electronic vandalism. People with Lepidoptera records from Kentucky to include in the database should contact one of the authors to receive a username and password. A convenient set of pull-down menus and text boxes allows rapid data entry, and users can correct or delete their own records that contain errors. Once entered, records are placed in an approval queue, but are not part of the searchable database until the records are approved by a database curator with administrative access. Administrative access is also password protected, and currently restricted to the authors of this paper. Database curators can approve records, deny them, or leave them in the queue pending receipt of further information (digital photos, specimens, or other opinions).

Queries by species. Species queries in Kentucky Butterfly Net can be initiated by entering either scientific or common names. Species query reports include range maps and phenology spindle diagrams dynamically generated from the records in the data, a complete list of which is also included in the report (Fig. 1). Also included in each species report are links to digital photos of mounted specimens for each species from the image libraries of the North American Moth Photographers Group (Patterson 2005), Tortricid Net (Gilligan 2008) and Nearctica.com (Poole 1999).

Queries by location. To facilitate the compilation of species lists for particular localities, location queries are available by county or by conservation unit. Locations can be selected by name or by clicking through a map-based interface. Some large conservation units span county boundaries, so records can be called up for portions of the unit or for the unit as a whole. County record lists include records from conservation units within the county. Location queries can produce a list of all Lepidopteran species, just butterfly species, or just moth species recorded from that location, with a link to the species query report for each taxon on the list.

RESULTS

To date, a total of 61,231 records describing 2,488 known species for the state of Kentucky are included in the database. Included among these are the records contained in published species lists for the state of Kentucky (Covell 1999, Covell & Gibson in press., Covell *et al.* 2000, Gibson & Covell 2006), records published in the Season Summaries of the Lepidopterists' Society and in the Newsletter of the Society of Kentucky Lepidopterists, as well as numerous unpublished observations.

The records cover the period of 1872–present, with the majority of records dating from the last 45 years. Each record corresponds to one or more specimens of a single species collected, photographed, or observed together on a single day in one of 244 geographic localities, corresponding to the 120 counties of Kentucky, plus an additional 124 conservation units (National Parks, National Forests, State Parks, Wildlife Management Areas, etc.). For a small minority of recent records, GPS coordinates are also available. Moth records are generally specimen-based. Butterfly records

include a mixture of specimen-based, photograph-based, and observation-based reports. Reports based on photographs or observations are indicated as such.

DISCUSSION

Education and public outreach. On-line databases such as Kentucky Butterfly Net can play an important role in raising public awareness about the Lepidoptera of a particular region. Casual visitors to the web site, especially those from understudied counties within the state, upon finding that many species are missing, frequently begin to document the species found within their area and report them. More formally, the database is used in conjunction with field collections in entomology and biodiversity courses at Western Kentucky University, and K–12 schools are beginning to take advantage of its availability as well. Since it went live in January 2007, over 1900 users have consulted the Kentucky Butterfly Net database.

Invasive Species. Kentucky Butterfly Net and other similar databases are very useful for monitoring invasive species. Information about the detection and spread of

KY Butterfly Net Database

Query Results

New Query

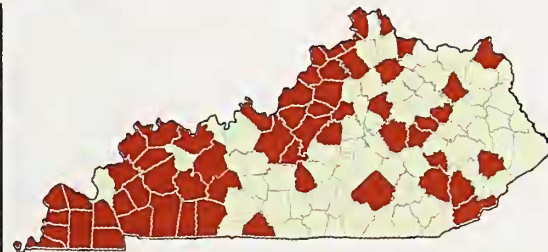
Family	Nymphalidae
Genus	Limenitis
Species	archippus
Common Name	Viceroy

Spindle Detail

Earliest Sighting: April 27
 Latest Sighting: October 10



Image © Robert W. Poole at Nearctica.com



Date of first observation: August 25, 1890
 Most recent observation: May 13, 2008

Date	# of Specimens	Location	County	Collected By	Determined By	Notes	GPS N	GPS W
May 13, 2008	1		Menifee	photo	Rita S. Adkins	Joe Harmon Rd, Frenchburg, Ky.		
September 19, 2007	1		Menifee	photo	Rita S. Adkins	On Joe Harmon Rd., about 2.5 miles South of Frenchburg		
September 8, 2007	1	Paducah	McCracken	Loran Gibson	Loran Gibson	Streetman's Property		
August 25, 2007	1		Meade	Loran Gibson	Loran Gibson	Lapland and Vicinity of Battletown		
June 17, 2007	1		McCracken	Loran Gibson	Loran Gibson	Littleville		
May 22, 2007	1		Bracken	Loran Gibson	Loran Gibson	Meldahl Dam		

FIG. 1. Example of a species query report from Kentucky Butterfly Net for the viceroy, *Limenitis archippus* (Cramer, 1776). This species is the state insect of Kentucky. Included in the report is a photo of the species, a dynamically generated range map, a dynamically generated phenology chart (or “spindle diagram”), the dates of the first and most recent observations of the species in the state, and a comprehensive list of records for the species. The list of records has been truncated for inclusion here.

such species needs to be shared quickly and must be accessible to as many interested people as possible, making web-based technologies particularly appropriate. There are a number of non-native Lepidoptera known from Kentucky, some of which, such as the meadow fritillary, *Boloria bellona* (Fabricius), invaded and spread from East to West through the state in less than 25 years, perhaps along the interstate highway system (Covell 1999). Another species, the European skipper *Thymelicus lineola* (Ochsenheimer), was present in the state for decades, becoming locally common in some areas, but did not spread as widely, and may now be extirpated since it has not been recorded from Kentucky since 1989 (Covell 1999). In 2000, Jonathan Smith collected the first Kentucky specimen of a Eurasian noctuid moth, *Noctua pronuba* (Linnaeus), which has been spreading throughout North America since its apparent introduction from Europe in 1979 (Covell & Gibson in press.).

Rare and Threatened Species. Databases such as Kentucky Butterfly Net are also important for monitoring populations of rare or threatened species. The distribution maps included in species reports can be used to illustrate to landowners the rarity of Lepidopteran populations on their properties and may help to enlist their cooperation in protecting those populations. It can also help governmental regulatory agencies and nonprofit conservation groups to identify populations that are in need of protection. Species that may fit these criteria in Kentucky include the Duke's Skipper, *Euphyes dukesi* (Lindsey), the broad-winged skipper, *Poanes viator* (W.H. Edwards), the Olympia marble, *Euchloe olympia* (W. H. Edwards), the Ozark Swallowtail, *Papilio joanae* (J. R. Heitzman), the Northern metalmark, *Calephelis borealis* (Grote & Robinson), the swamp metalmark, *Calephelis mutica* (McAlpine), and the rattlesnake master borer moth, *Papaipema eryngii* (Bird). It can also help identify outlying populations of species that are geographically and possibly also genetically distinct from the rest of the species distribution. An example may be the population of brown elfin butterflies *Callophrys augustus* (Kirby) discovered in Mammoth Cave National Park in 2005 by Ian Segebarth during a Lepidoptera inventory, which is over 200 km away from the nearest known neighboring population of that species.

Global Climate Change and Habitat Loss. Lepidoptera are frequently used as indicator species because many species (especially butterflies) are easy to observe and identify and also respond to changes in habitat very quickly. The United Kingdom Butterfly Monitoring Scheme in particular has provided

important insights into the effects of habitat loss and climate change on Lepidopteran populations (Warren *et al.* 2001). Kentucky Butterfly Net reveals several different ways in which Lepidopteran populations respond to climate change.

First, Lepidoptera respond by changing their phenology and emergence times. The Olympia marble butterfly, *Euchloe olympia* has a single brood each year in the early spring, with adults flying for a period of about two weeks, typically centered around 15 April. In late March 2007, presumably in response to unseasonably warm weather (daily highs of 32–35 C), *E. olympia* emerged early in disparate areas of the state, emerging by 24 March in Owsley County and by 2 April in Mammoth Cave National Park, Edmonson County. These are the two earliest emergence times for *E. olympia* on record in Kentucky, and 2–3 weeks earlier than in a typical year. The third earliest Kentucky record for this species is from 7 April 1963 by Jack Dempwolf, from Natural Bridge State Resort Park in Powell County.

Species also respond by shifting their ranges. Kentucky seems to be experiencing an increase in the occurrence of migrants from the South. In 2008, two different individuals photographed a small pink moth, *Pyrausta inornatalis* (Fernald)(Crambidae), known before only from Texas to Tennessee. Southern butterfly species rarely seen in Kentucky have been recorded in recent years more often, and also earlier in the season. These colonize northward into Kentucky, become frequent in late summer, then die back in winter. Species in this category include the long-tailed skipper, *Urbanus proteus* (Linnaeus), and the Gulf Fritillary, *Agraulis vanillae* (Linnaeus). Oldham County, Ky. July 4th butterfly counts, conducted since 1976 around the beginning of July by Covell, reveal that one cloudless sulfur, *Phoebis seunae* (Linnaeus), was seen in 1992—a unique occurrence from 1976 to 2002—while 6–17 individuals were counted in each year, 2004–2007. Similarly, two individuals of the sleepy orange, *Eurema nicippe* (Cramer), were recorded in 1992 as the only occurrences between 1976 and 2000. In 2001, 4 were seen, and 44 have appeared in 2003–2008. The gemmed satyr, *Cyllopsis gemma* (Hübner), was not found at all until 1999 since which a total of 43 have been seen. In like manner, the Carolina Satyr, *Hermeuptychia sosybius* (Fabricius) was first discovered at the study site in 2002, and has since been seen there in 3 of the six subsequent counts (Covell unpublished).

However, when these observations are paired with a third pattern, the apparent disappearance of several “Northern” species that used to be observed in Kentucky, suspected effects of climate change become

even more apparent. Species in this category include the regal fritillary, *Speyeria idalia* (Drury), not seen since 1972, the green comma, *Polygonia faunus* (W. H. Edwards), not seen since 1973, and the gray comma, *Polygonia progne* (Cramer), not reported since 1977. These apparent disappearances have occurred in spite of considerable effort to find these species, so changes in collector effort cannot be used to explain the disappearance of these species.

It is possible that each of these changes is caused by factors other than global climate change, but taken together they indicate the Lepidopteran fauna of Kentucky is clearly changing in a manner consistent with a gradual increase in average annual temperatures.

Future directions. We hope to continue to develop tools to facilitate research and educational activities that take advantage of Kentucky Lepidoptera distribution data. We are particularly looking forward to developing connections between Kentucky Butterfly Net and other projects involving Lepidoptera in Kentucky such as the Upper Green River Barcode of Life Project (Marcus *et al.* 2010, unpub. data). We would also welcome the opportunity to help others develop web database applications for collecting and sharing distribution data for both Lepidoptera and other organisms.

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